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ABSTRACT

Researchers have suggested a language factor as an obstacle in the mathematics learning process for students who do not have a command of English. A review of the literature is presented, focusing on the nature of the interaction between language and mathematics learning. Implications for the design of instructional activities are presented, with particular note that a certain level of language proficiency must be attained by students learning mathematics in English as a second language, and that metacognitive strategies must be incorporated in the overall instructional design. The 3-year study discussed in this paper addressed the need to identify areas of difficulty, develop a general process approach model, train a group of teachers to use the model, and evaluate the effects of the training on the basis of student achievement in mathematics. Overall, the results of the study indicated that it is possible to integrate language and content teaching with favorable results in terms of mathematics achievement in second language learners. (MNS)

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THE EFFECTS OF A LANGUAGE PROCESS
APPROACH PROGRAM ON THE MATHEMATICS
ACHIEVEMENT OF FIRST, THIRD AND FIFTH GRADERS

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INTRODUCTION

The language used to convey mathematical ideas is a concern to educators who are responsible for providing instruction to students who are not proficient in the English language. Evidence of the magnitude of this problem can be found in the results of a study conducted by the National Center for Educational Statistics (NCES) which show that the number of limited English proficient (LEP) students is projected to increase from the 1980 level of 2.4 million to 3.4 million by the year 2000 (NCES, 1981). There is also evidence in the literature that one of the reasons for the language minority student's under achievement in school is her/his lack of mastery of English as a second language (Valverde, 1984). More specifically, researchers have suggested a language factor as an obstacle in the mathematics learning process for these students who do not have a command of English (Dawe, 1983; Cuevas & Llabre, 1981; Austin & Howson, 1974; Coffland & Cuevas, 1979; Kessler & Quinn, 1980).

In recent years a number of conferences and professional meetings have addressed the "language-mathematics learning" issue (Note 1). The participants of these conferences have called for a systematic plan of research to investigate the role language plays in the learning of mathematics. In addition, the conferences have addressed the need to identify language difficulties students have in mathematics, as well as instructional strategies which may help the learner overcome these problems. A basic approach to research in this area can be described through a number of questions which address the steps suggested by studies presented and discussions conducted at the above mentioned meetings:

1. First, what specific difficulties do second language learners experience in areas of mathematics such as concept development, computation, and applications (word problems)?

2. What language structures/skills appear to occur frequently in the teaching/learning of mathematical concepts, computations and applications?
3. Can instructional strategies based on the language structures/skills identified be developed to address the language problems language minority students experience in mathematics?
4. If such instructional strategies can be developed, what are the skills that teachers need to implement language related activities in the mathematics classroom?
5. And last, can students improve their mathematics achievement as a result of the instructional strategies provided by the teachers?

REVIEW OF THE LITERATURE

Underlying all of the above questions is a more general issue - what is the nature of the interaction between language and mathematics learning? The literature in this area is not conclusive; it indicates that a relationship exists between language skills and mathematics learning. Studies indicate that there is a positive correlation between reading ability and scores on tests of problem solving in arithmetic (Aiken, 1971). There is also evidence in the literature of a positive correlation between mathematics performance and second language ability (Cossio, 1978). In addition, there appears to be a relationship between instruction through the student's native language in curriculum content areas and high achievement in those areas (Granado, 1976; Tsang, 1976, 1984; Coffland and Cuevas, 1979; Cuevas and Llabre, 1981). In summary, the relationship between language factors and mathematics achievement is not clearly understood, but it may be appropriate to assume that in order for a student to master mathematics concepts, the language in which the concepts are presented must be first mastered.

Language skills and mathematics achievement

The learning of the language in which concepts are presented involves, to a great extent, the mastery of meanings which serve a particular function in the language, as well as the words and structures which convey those meanings. This is what linguists term a language register. Halliday (1974) has referred to a "mathematics register" as the set of meanings that belong to the language of mathematics. He suggests that this "mathematics register" is more precise than natural language since the meanings of the terms used are very narrow in scope. It has been hypothesized that the "mathematics register" is composed of:

- a. Natural language words reinterpreted in the context of mathematics. Some of the words are set, point, field, column, sum, even (number), random.
- b. "Locutions" such as right-angled triangle, and lowest common multiple.
- c. Terms created from combinations of natural language words such as feedback and output.
- d. Terms formed by combining elements of Greek and Latin words. Examples include parabola, denominator, coefficient.

Vocabulary is not the only dimension of the "mathematics register" which needs to be addressed in instructional activities. Styles of meaning and ways in which arguments are presented as part of the "language of mathematics" must also be considered. Examples of these include such expressions as "the sum of the series to n terms".

Hargis and Knight (1977) add that since mathematics is the study of relationships, the mathematics register contains a number of comparative structures, such as more/less than, n times as much, -er than and as...as to express that function. Furthermore, Munro (1979) also cites the frequent use of prepositions and the passive voice to convey a particular operation, especially division, as in "eight divided by two" versus "eight divided into two."

On a level above vocabulary and syntax, the discourse level of language, the meaningful "chunks" of math language or math "texts", both written and spoken, have characteristics particular to the math register. Math texts are organized around a logical sequence of math skills and principles rather than around theme organization and conversational or literary style, as in natural language. As Coulter (1972) states, understanding these texts requires manipulation of quantitative concepts, key procedural words and computational processes. Written math texts lack redundancy. Multiple math operations are often coded in a single math statement requiring the reader to mentally manipulate the compacted information of the problem in order to determine how the elements of the text are related temporally, spatially, or comparatively.

This "mental manipulation" mentioned has been referred in the literature as metacognition or metacognitive strategies. Although the definition of the term has been argued by some, it can be concluded that "metacognitive strategies" involves two skill areas - "... one's knowledge concerning one's own cognitive processes ..." and "... the active monitoring and consequent regulation ... of these processes." (Flavell, 1976, p. 323). Related to the role of metacognition in mathematics learning is the issue of the relationship of language and thinking. Some researchers have suggested that language determines and defines thought. Others such as Piaget (1956), have tended to accept only a limited effect of language on thought. He insists that language development in children depends to a great extent on prior cognitive learning. Thought for Piaget is "internalized action." Linguists also differ in their views concerning language and thought. Chomsky (1969) theorizes that language is not dependent upon other aspects of cognitive development for its emergence and development. He feels children are born with "a language acquisition device." Vigotsky (1962) hypothesizes that there can be language without thought and thought without language. He

points at the fact that children can learn and use words and sentences without completely knowing what they mean. Vigotsky also believes that after age two, language and thought merge to produce "verbal thought," a term somewhat obscure in its nature. Regardless of the theory, it may be assumed that language does play a role in the "thinking/metacognitive" process.

Many psycholinguists and researchers emphasize the fact that linguistic competence is multidimensional. The intricate language functions which require particular language skills as, for example, those involved in literacy, are unmistakably different from the skills which an individual would use to engage in an informal social conversation. The kind of language used in this type of interaction has been described as "situated" or "context-embedded" (Cummins, 1981) where the actual situation in which the conversation is produced provides the participant the means to interpret the language aspects of what has taken place. There are other cues which give the learner support such as accompanying gestures, intonation, pacing, and tone of voice. There is, by contrast, what has been described as "decontextualized" language. (Cummins, 1981) this is the language which is found in textbooks or that which is used in formal instruction.

Implications for the design of instructional activities

It can be concluded from the review of the literature that a certain level of language proficiency must be attained by students learning mathematics in English as a second language. Morris (1974) has recommended that mathematics is not easily learned by students if they merely write symbols on their papers, rearrange them, getting "answers", or by copying the mathematical processes and learning them by heart. Instead, he says, students must be

involved in structured activities, which include investigations and discussions which will ensure understanding. In summary, Morris (1974) states that "... the teaching of mathematics in a second language must, in effect, adopt the principles which govern the methods of teaching a second language as a language." (p. 52)

In addition to the use of second language approach in mathematics instruction for second language learners, there is a need to incorporate metacognitive strategies in the overall instructional design. Brown and Palincsar (1982) have suggested a "self-regulation" approach to the use of metacognitive strategies. This method involves supplementing instruction by providing students with information relative to the planning, monitoring, and assessment of problem solving strategies. The basic purpose is to have students incorporate approaches used by an "expert problem solver". Brown, et al (1981) have shown that this particular metacognitive teaching method has been successful with students in reading tasks with respect to transfer of skills.

PURPOSE

The purposes of the study were to:

- a. identify areas of difficulty in mathematics at the elementary school level experienced by second language learners;
- b. given the existing research literature, develop general "process approach" model which takes into account language and metacognitive aspects in learning mathematics;
- c. train a group of selected teachers on the process-approach model;
- d. and, evaluate the effects of the training on the basis of student achievement in mathematics.

Activities which addressed these objectives were conducted over a three-year period from 1982 - 1984.

Research questions

The primary focus of the R & D study was not on hypothesis testing, but on the development and exploration of teaching strategies designed to help second language learners overcome certain difficulties in mathematics. The basic five questions addressed were presented in the introduction to this paper.

A PROCESS APPROACH MODEL

The overall process stems from the problem, e.g., the need for mathematics materials which address the language needs of limited English proficient students. Specifically, in order for these students to master the mathematics concepts presented in the classroom, the language of the concepts must be mastered. In addition to organizational patterns which have limited value, curricula and instructional materials which address language problems in mathematics are either scarce or when available, not appropriate.

The "Process Approach" to language/mathematics teaching used in the study addressed two interrelated cognitive subareas; the linguistic analysis of computation, concepts, and applications (word problems) as well as the utilization of "self-regulated" metacognitive strategies. Table I presents the components of the "Process Approach" together with the teaching approaches to be addressed by the component and the research reference for the use of such approaches.

The implementation of the "Process Approach" is guided by a set of premises which provide overall direction in the planning and carrying out of instructional activities.

1. The important principle is that the teacher and student agree that the skill area under study is important and needs to be learned.
2. The instructor verbalizes where the skill fits into the scheme of skills including the subskills.

TABLE I
A LANGUAGE PROCESS APPROACH TO MATHEMATICS
TEACHING: ANALYSIS OF COMPONENTS

Component	Teaching Approaches	Research Reference
1.0 Concept/Skill Identification		
1.1 Mathematics	1.1.1. Determine instructional objective(s)	Clark & Yinger (1978)
	1.1.2. Determine prerequisite skills necessary mastery of objective(s)	Clark & Yinger (1978)
1.2 Language	1.2.1. Identify key vocabulary	Halliday (1974); Chamot (1982)
	1.2.2. Illustrate meanings of terms identified	Hargis & Knight (1977); Brunner (1976); Clark, R/(1974)
2.0 Identification	2.1 List the vocabulary in context noting aspects of grammar	Munro (1979); Coulten (1972)
3.0 Development of Activities		
3.1 Mathematics	3.1.1. Follow curriculum guide; teacher's edition or other teacher-based materials for the development of content	
3.2 Language	3.2.1. Incorporate second language teaching techniques	Morris (1975)
	3.2.2. Utilize "self-regulated" metacognitive strategies (word problems)	Brown, et al (1981)

3. The students reverbitalize the instructor's analysis.
4. The instructor shows the students how to practice the skill in a variety of ways.
5. The students practice the skill as the instructor observes and gives feedback.
6. The students practice the skill and self-check. The instructor helps when needed.
7. The students extend the skill into other kinds of problems (generalization) and in different settings.
8. The students take the skill home for successful explanation and reinforcement.

Given these basic premises and the general components of the "Process Approach", the following procedure was used by teachers in preparing lesson plans.

1. Linguistic Focus

The linguistic focus needs to address the following:

- a. Vocabulary development - A developmental vocabulary list was used that contained words that are inherent in the linguistic aspects of the skill being taught. These are words that the student is most probably unfamiliar with, yet needs to master in order to achieve competency in the particular skill.
- b. Review of structures - The meaning of certain mathematical terms and expressions are found in this list, as well as ordinary structures used in everyday language which may be unfamiliar to the student, but make it simpler for the teacher to teach the skill by using colloquial expressions, phrases, and structures.

2. Mathematics Focus

The mathematics content of the lesson is described, and the mathematics vocabulary to be introduced is identified.

- a. Vocabulary review - The review vocabulary list contains words that have already been taught. These words must be reviewed, however, since they appear as part of the objective. The student needs to show understanding of the words before continuing on to a new concept.

RESEARCH SUMMARY

Sample

The sample consisted of six schools, randomly selected from schools in the district which are representative of Hispanic (Cuban, Mexican American) and Haitian populations. The breakdown of the schools in the sample is given in Table II. From this group of schools, intact classes at the first, third, and fifth grade levels were randomly assigned to either an experimental or control group. These intact classes had a substantive representation of limited English proficient (LEP) students. Table III shows a breakdown of the students by home language.

TABLE II
NUMBER OF STUDENTS BY TREATMENT, SCHOOL AND GRADE

<u>Schools</u>	<u>G R A D E S</u>			<u>Total</u>
	<u>1</u>	<u>3</u>	<u>5</u>	
Control #1	14	19	25	58
Experimental #1	14	22	22	58
Control #2	20	24	15	59
Experimental #2	23	17	16	56
Control #3	14	31	0	45
Experimental #3	14	20	0	<u>34</u>
				310

Table II shows a breakdown of the students by home language. The composition of these groups reflect the overall population language make-up present in the Dade County Schools.

TABLE III
BREAKDOWN OF STUDENTS BY HOME LANGUAGE

	<u>EXPERIMENTAL</u>			
GRADE	1	3	5	
ENGLISH	18	18	8	44 (30%)
SPANISH	24	32	29	85 (57%)
CREOLE	<u>9</u>	<u>9</u>	<u>1</u>	<u>19</u> (13%)
	51	59	38	148

	<u>CONTROL</u>			
GRADE	1	3	5	
ENGLISH	6	18	15	39 (24%)
SPANISH	36	40	25	101 (62%)
CREOLE	<u>6</u>	<u>16</u>	<u>0</u>	<u>22</u> (14%)
	48	74	40	162

	EXPERIMENTAL	CONTROL	OVERALL
ENGLISH	30%	24%	27%
SPANISH	57%	62%	60%
CREOLE	13%	14%	13%

Procedure

Teachers in the "experimental" schools received eight hours of training in the Language Process Approach to Mathematics Teaching. The training was followed by bi-monthly observation and brief interaction visits to ensure that the teaching behaviors presented in the training were implemented. During these visits the researchers discussed the teacher's approaches to the implementation of the treatment.

Teachers in the "control" schools were similarly visited in order for the researchers to provide them with suggestions about current techniques for teaching mathematics to LEP children. Both treatments took place from October 1984 through May 1985.

The following instrument was administered on a pre/post basis to all students in order to assess the effectiveness of the instructional approach: The Comprehensive Test of Basic Skills was administered to all students in the sample. The pre-test was given in the latter part of October 1984; the post-test during the latter part of May 1985.

Analysis of data and results

The Statistical Package for the Social Sciences (Nie, et al, 1975) was used in the data analysis. Analysis of covariance was performed, with the pre-test scores used as covariate. Table IV shows the summary of the results.

Results indicate a significant difference between experimental and control groups' scale concept/application in the first grade and for computation scores in third grade. In both instances the experimental group outperformed control group.

Although the third and fifth grades differences in concept/application between the experimental and control groups were not significant, they

TABLE IV
Comparison of Mean Posttest Scale Scores
Between Groups Using Pretest Scale Score
as a Covariate

COMPUTATION									
Grade-Mean	EXPERIMENTAL				CONTROL				P
	PRE	N	POST	N	PRE	N	POST	N	
1 Mean			401	58			361	51	
(a)GE									
3 Mean	602	59	662	59	588	74	638	74	.003 **
GE	3.1		4.1		2.9		3.6		
5 Mean	699	38	709	38	679	40	706	40	.506 (NS)
GE	5.4		6.2		4.6		5.9		

CONCEPTS/APPLICATIONS

Grade									
1 Mean	359	51	510	51	363	48	479	48	.032 *
GE	.7		1.8		.7		1.6		
3 Mean	592	56	627	56	564	73	600	73	.086 (NS)
GE	2.7		3.6		2.3		2.9		
5 Mean	638	36	676	36	661	26	671	26	.062 (NS)
GE	4.0		5.7		4.9		5.4		

(a) GE = Grade Equivalent

** $p < .01$

* $p < .05$

were substantial in the direction hypothesized. Four out of five group comparisons were either significant or highly suggestive of experimental performance over the control group.

A content analysis of the concept/application subscale was conducted to identify those test items which assessed concepts and those which measured performance in applications (word problems). It was found that at the first grade all of the items (except one) assessed concepts, while there was a balance in the distribution of items in grades third and fifth. Separate raw pre and posttest scores were derived at these grades for concepts and applications. An analysis of covariance was performed using the pretest raw scores as covariates. Tables V and VI show a summary of the results. The results indicate significantly higher scores for applications (word problems) at the third grade for the experimental group. For concepts, the experimental group outperformed the comparison group at the fifth grade.

DISCUSSION OF RESULTS

It was the purpose of this research study to address a number of questions concerning the relationship of language skills to performance in mathematics. From the questions posed earlier in this paper, the following will be addressed:

First, do students for whom English is a second language experience difficulties in the learning of mathematics?

Data collected preliminary to the study pointed to difficulties in student performance in the areas of understanding of concepts and solution of word problems. Computational difficulties were largely due to the use of algorithms not used in U. S. schools.

Second, can instructional strategies be developed to address the language problems language minority students experience in mathematics, given the knowledge we have regarding the relationship between language and mathematics learning?

TABLE V
Comparison of Mean Posttest Raw Scores
for Concept Between Groups Using Pretest
Raw Scores as a Covariate

GRADE	EXPERIMENTAL (N = 59)		CONTROL (N = 74)		P
	PRE	POST	PRE	POST	
3	15.38	19.53	12.84	17.10	(NS)
5	8.72	14.94	11.76	14.28	*

TABLE VI
Comparison of Mean Posttest Raw Scores
for Applications Between Groups Using
Pretest Raw Scores as a Covariate

GRADE	EXPERIMENTAL (N = 38)		CONTROL (N = 40)		P
	PRE	POST	PRE	POST	
3	8.13	10.83	6.61	8.61	**
5	9.30	12.03	11.48	12.72	(NS)

* $P < .05$

** $P < .01$

The overall picture which emerges from research studies concerning language minority students and mathematics achievement is neither clear nor conclusive. From the work of Cummins (1981) and Halliday (1974) and the instructional methodologies found in the fields of foreign language and English as a second language teaching, strategies can be developed to address language factors in the learning of mathematics. From the results of this study it can be concluded that certain teaching skills can be identified (see Table I) and training provided so teachers can develop/adapt activities which address language and metacognitive components of mathematics instruction.

Third, can students improve their mathematics achievement as a result of the "language-oriented" instructional strategies provided by teachers?

The results of the study indicate a trend in mathematics performance which favors the utilization of language and metacognitive-oriented teaching strategies for language minority as well as English language majority students. This points to the existence of a relationship between mastering of certain linguistic structures and skills and performance in mathematics. In conclusion, given the nature of the mathematics register of English, students must be able to use identified language skills in order to successfully perform in mathematics at the elementary school level. These results raise questions concerning the specific nature of the relationship between language and mathematics learning.

- a. What specific language structures (mathematics register) appear to occur frequently in the teaching/learning of mathematical concepts, computations and applications?

Because of financial constraints on the project, this is an area which was not investigated in detail. Language structures were addressed in the training of teachers in the general sense. (see Note 2 for comments on current progress in this area).

- b. What is the relationship of specific teaching behaviors to student outcomes?

Given the fact that the "process approach" model addressed general teaching behaviors, teachers were left to modify these general approaches to fit their "teaching styles". The researcher only made sure that general strategies presented in the training were followed. Further research needs to be performed in this area to identify specific elements of the mathematics register, teaching strategies which address these elements of the register and student outcomes in mathematics.

Overall, the results of study indicated that it is possible to integrate language and content teaching with favorable results in terms of mathematics achievement in second language learners.

REFERENCE NOTES

1. Some of the conferences that have addressed the interaction of language and mathematics are: the Nairobi Conference (1974) organized by UNESCO; the Accra Conference (1975) organized by the Commonwealth Association for Science & Mathematics Education; and the Mathematics Equity Conferences (1983), organized by the U. S. National Council for Teachers of Mathematics (NCTM).
2. The Center for Applied Linguistics is currently carrying out a project funded by the Fund for the Improvement of Post-Secondary Education (USOE), which addresses this concern in the area of algebra at the community college level.

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